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FLIGHT INVESTIGATION OF THE PERFORMANCE
OF A TWO-STAGE SOLID-PROPELLANT NIKE-DEACON (DAN)
METEOROLOGICAL SOUNDING ROCKET

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OF A TWO-STAGE SOLID-PROPELLANT NIKE-DEACON (DAN)
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SUMMARY

Two Nike-Deacon (DAN) two-stage solid-propellant rocket vehicles were flight tested to evaluate their use as meteorological sounding rockets. The vehicles contained upper atmosphere research apparatus which was ejected in flight, and the flight paths were determined by using radar beacon instrumentation. The radar beacon instrumentation recorded a peak altitude of 356,000 feet during the first flight test and 350,000 feet during the second flight test when both vehicles were launched from sea level at an angle of elevation of 75°. Satisfactory performance of the DAN meteorological sounding rocket was indicated from the results of the flight tests conducted. Performance calculations based on flight-test results show that altitudes between 358,000 feet and 487,000 feet may be attained with payloads varying between 60 pounds and 10 pounds.

INTRODUCTION

At the request of the U. S. Air Force Cambridge Research Center, the Langley Pilotless Aircraft Research Division of the National Advisory Committee for Aeronautics assisted the Engineering Research Institute of the University of Michigan in developing an upper atmosphere meteorological sounding rocket. A two-stage solid-propellant combination using a Nike booster with a second-stage ABL Deacon sustainer, which had previously been used by the NACA as an aerodynamic research vehicle, was adapted as a meteorological sounding rocket. Two flight tests to obtain performance evaluations of this vehicle, henceforth referred to as DAN, were conducted at the Langley Pilotless Aircraft Research Station at Wallops Island, Va.

¹The information presented herein was previously made available to the U. S. military air services.

The DAN sounding rocket is intended to carry the free-fall accelerometer sphere apparatus developed by the Engineering Research Institute of the University of Michigan in order to measure densities of the atmosphere at altitudes between 250,000 and 375,000 feet (ref. 1). It is a desirable combination because of the basic simplicity of transportation, assembly, and launching possible with the use of solid-propellant rocket motors having high take-off accelerations.

This report presents the configuration, the flight-test results, and the zero-length launching method used. The flight-test results are presented in the form of data for trajectories, velocities, accelerations, and drag. These data are required for determining the ability of the DAN meteorological sounding rocket to fulfill the needs of any particular extreme-altitude research mission.

SYMBOLS

a_x	longitudinal acceleration, ft/sec ²
D	drag, lb
C_D	drag coefficient, D/qA_F
g	acceleration due to gravity, at altitude $g_0 \frac{R^2}{(R + h_0)^2}$, ft/sec ²
g_0	acceleration at sea level due to gravity, 32.172 ft/sec ²
h	altitude, ft
h_0	altitude, miles
M	Mach number
N_{Re}	Reynolds number per foot of length
q	dynamic pressure, lb/sq ft
r	horizontal range, ft
R	radius of the earth, miles
A_F	frontal area, sq ft
V	velocity, ft/sec
t	time, sec

DESCRIPTION OF THE VEHICLES AND LAUNCHER

Both sounding-rocket vehicles employed a two-stage solid-propellant propulsion system consisting of a first-stage Nike booster and a second-stage ABL Deacon sustainer. A photograph of the combination on the zero-length launcher is shown in figure 1. The first-stage Nike booster consisted of three parts: a steel adapter and magnesium coupling at the head end of the booster rocket, the rocket motor, and a fin assembly consisting of four fins (sandwich construction consisting of 1/16-inch-thick duralumin sheets glued to a laminated wood core) attached to a cast-magnesium shroud. The second-stage Deacon sounding rocket consisted of three major components: the instrument housing assembly consisting of an 11° apex angled nose cone and a tapered steel section, the Deacon sustainer rocket motor, and the fin assembly consisting of four tapered duralumin fins attached to a cylindrical shroud.

A sketch of the two-stage Nike-Deacon (DAN) combination with pertinent dimensions and center-of-gravity locations is shown in figure 2. The configuration and dimensions of both sounding rockets were identical. The fins of the second stage were interdigitated approximately 45° with the booster fins. The weights of both sounding-rocket combinations were the same, differing only in the additional 5 pounds of the second stage of sounding rocket no. 2. The weights of the various components are presented in the following table:

Loaded booster, lb	1,170
Booster adapter, lb	45
Booster fins, lb	109
Complete booster, lb	1,324
Loaded Deacon, lb	151.5
Deacon fins, shroud, and fairing ring, lb	25.5
Nozzle extension, lb	5.0
Nose cone and instrumentation, lb	34.0 for no. 1 39 for no. 2
Complete Deacon second stage, lb	216.0 for no. 1 221 for no. 2

Figure 3(a) shows a photograph of the assembled nose cone of the second stage. The cast-magnesium shell houses the AN/DPN-19 radar beacon instrumentation. Because of the aerodynamic heating, a 3/16-inch thickness was required for the magnesium shell. A theoretical heat-transfer calculation, based upon a coast period of 12 seconds between the booster and the second-stage firing, gave a skin temperature of 550° F at a station 24 inches from the point of the nose.

The position of the accelerometer sphere enclosed within the nose cone is represented in figure 3(b). In order to release the University of Michigan accelerometer sphere, the duralumin retainer ring is exploded and a stiff spring pushes the sphere and nose-cone section away from the

second-stage rocket motor. A weaker spring then pushes the accelerometer sphere away from the nose cone. Figure 4(a) shows a sketch of the nose cone and sphere being separated from the second-stage rocket by exploding the retainer ring. Figure 4(b) shows the sphere separating from the nose cone.

A zero-length launcher was used as shown in figures 1 and 5. A detailed photograph of the launching fittings is shown in figures 6 and 7. Figure 6 shows the forward fitting hooked into the spring-loaded arms that fly apart to clear the rear booster fin when the two-stage vehicle is launched. Figure 7 shows the rear fitting consisting of an adjustable stud placed in a socket of the booster shroud. A single forward folding arm may be used in place of the two spring-loaded arms, and the rear fitting may be placed between two of the fins on the shroud.

INSTRUMENTATION

The NACA SCR 584 modified tracking radar unit tracked a signal from the AN/DPN-19 radar beacon housed within the nose cone of the sounding rocket and provided slant range, azimuth, and elevation angle from which altitude, horizontal range, and flight-path angle may be calculated at a given time. A rawinsonde, a balloon that was launched before the time of flight, provided measurements of static pressure, static temperature, and balloon azimuth and elevation to altitudes in excess of 60,000 feet. Wind velocity and direction were calculated from these data.

The CW Doppler radar unit afforded the variation of velocity with time. The velocities thus obtained were then used with values of the speed of sound in order to obtain Mach number. The speed of sound was calculated from static-temperature measurements obtained from the rawinsonde.

FLIGHT-TEST PROCEDURE

Both flight-test DAN sounding rockets were launched at an angle of elevation of 75° from horizontal. This was the maximum launching angle permitted by safety restrictions at the firing range at the Langley Pilotless Aircraft Research Station at Wallops Island, Va. Both second-stage rockets were allowed to decelerate after booster separation. The coast period permitted the vehicles to traverse the lower, denser atmosphere at lower velocities, thereby reducing the maximum outer wall temperatures of the nose cone and rocket case as well as lowering the aerodynamic drag. The optimum duration of the coasting period for attainment of maximum altitude was estimated to be 10 to 14 seconds,

according to performance calculations. This variation in coast period was not critical. Since the burning time of the Nike booster first stage was approximately 3.5 seconds, a nominally 15.5-second time-delay powder squib, electrically ignited, was employed in the Deacon second stage in order to give a nominal coasting period of 12 seconds and permit ignition of the squib at the instant of launching. The accuracy of the time delay of the 15.5-second time-delay squib is about 1.0 second. In the flight test of the first DAN sounding rocket, the squib gave a delay of about 17 seconds. Accordingly, in the second DAN sounding-rocket test, a nominally 13.5-second time-delay squib was employed which in the flight test gave a delay of about 12.8 seconds. The nose cone and accelerometer sphere were to be released from the Deacon second stage at 52 seconds after ground launching; at this flight time, the calculated ratio of second-stage drag to weight was 1 percent or less. Figure 8 illustrates the sequence of events in the flight test of the sounding rockets.

RESULTS AND DISCUSSION

Flight-Test Results

The first DAN vehicle was launched at an angle of elevation of 75° . The second stage was boosted to an altitude of 4,900 feet. The booster then separated from the second stage since the deceleration of the burned-out booster was greater than that of the second-stage sustainer. The second stage coasted 13.7 seconds before the rocket fired and was accelerated to a maximum velocity of 5,150 feet per second at an altitude of 47,060 feet. After burnout, the second stage coasted in free flight, gaining altitude. The ejection mechanism released the nose cone and sphere at 52 seconds after launching took place. A peak altitude of 356,000 feet was determined from the AN/DPN-19 radar beacon in the nose cone at 161 seconds after ground launching. The radar beacon was tracked along the trajectory down to a 53,000-foot altitude. The estimated range upon impact was 340,000 feet.

The second DAN vehicle was launched at an angle of elevation of 75° . The second stage was boosted to an altitude of 5,200 feet; then the booster separated. The second stage then coasted 9.45 seconds before the rocket fired and was accelerated to a maximum velocity of 5,289 feet per second at an altitude of 39,339 feet. After burnout, the second stage coasted in free flight, gaining altitude. The ejection mechanism again was timed to release the nose cone at 52 seconds after launching took place. A peak altitude of 350,000 feet was determined from the AN/DPN-19 radar beacon in the nose cone. The radar beacon was tracked intermittently during the ascension of the second flight. A beacon-signal recording was obtained for $1/2$ second of flight time between 29,048- and 29,762-foot altitudes. A beacon signal was not tracked

again until just before peak altitude. The flight path was then beacon tracked downward to a 144,000-foot altitude. The impact point was estimated to be 320,000 feet in range. By reconstruction of the ascension of the second-stage flight path from the data obtained, peak altitude was found to be reached in 156 seconds.

Figure 8 shows trajectory plots of the two DAN vehicle combinations. The solid portion represents the tracking of the radar beacon, whereas the dashed lines indicate the estimated or reconstructed portion of the flight path. Figure 8 also illustrates the sequence of events that take place from launching, second-stage separation, second-stage ascension, sphere and nose-cone ejection, and the Deacon rocket, sphere, and nose-cone flight paths. Figure 9 represents the variation of altitude with flight time for both flight tests to the apex of the trajectory.

The variation of velocity with flight time for both combinations of booster and second stage, as recorded by the CW Doppler radar instrumentation for the first 23 seconds, is presented in figure 10. The coast periods are indicated by a dashed line.

The variation of drag coefficients with Mach number for the coast periods of the second stage is presented in figure 11. Figure 12 presents the variation of Reynolds number per foot of length with Mach number calculated from the velocities obtained from the CW Doppler radar in conjunction with densities and temperature determined from the rawinsonde measurements.

Performance Considerations

Performance of the DAN sounding rocket may be calculated for different payloads from the data obtained from the two flight tests. For most extreme altitude experiments, near-vertical launching angles will be used. From the data obtained from the DAN flight tests, the variation in altitude with change in payloads may be calculated. The payload is that instrumentation required other than the loaded rocket, fins, shroud, and nose cone. The calculated variation of peak altitude with change in payload for a vertical launching is shown in figure 13. The highest altitude of 487,000 feet represents a 190-pound second stage of which 10 pounds is payload. The lowest altitude of 358,000 feet represents a 250-pound second stage of which 60 pounds is payload. In order to determine the necessary limitations that might be required of any instrumentation due to acceleration of the DAN sounding rocket, a plot of absolute longitudinal acceleration with time is presented in figure 14.

CONCLUDING REMARKS

Two Nike-Deacon (DAN) sounding rockets were successfully flight tested to determine the drag, trajectories, some velocity and acceleration information. The flight tests demonstrate that this two-stage solid-propellant sounding rocket operates satisfactorily with respect to both propulsion and aerodynamics. Altitudes between 385,000 and 487,000 feet may be attained with payloads varying between 60 and 10 pounds when the DAN is launched vertically.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 5, 1955.

REFERENCE

1. Bartman, F. L.: Falling Sphere Method for Upper Air Density and Temperature. Rocket Exploration of the Upper Atmosphere, R. L. F. Boyd and M. J. Seaton, eds., Interscience Publishers, Inc. (New York), and Pergamon Press Ltd. (London), 1954, pp. 98-107.

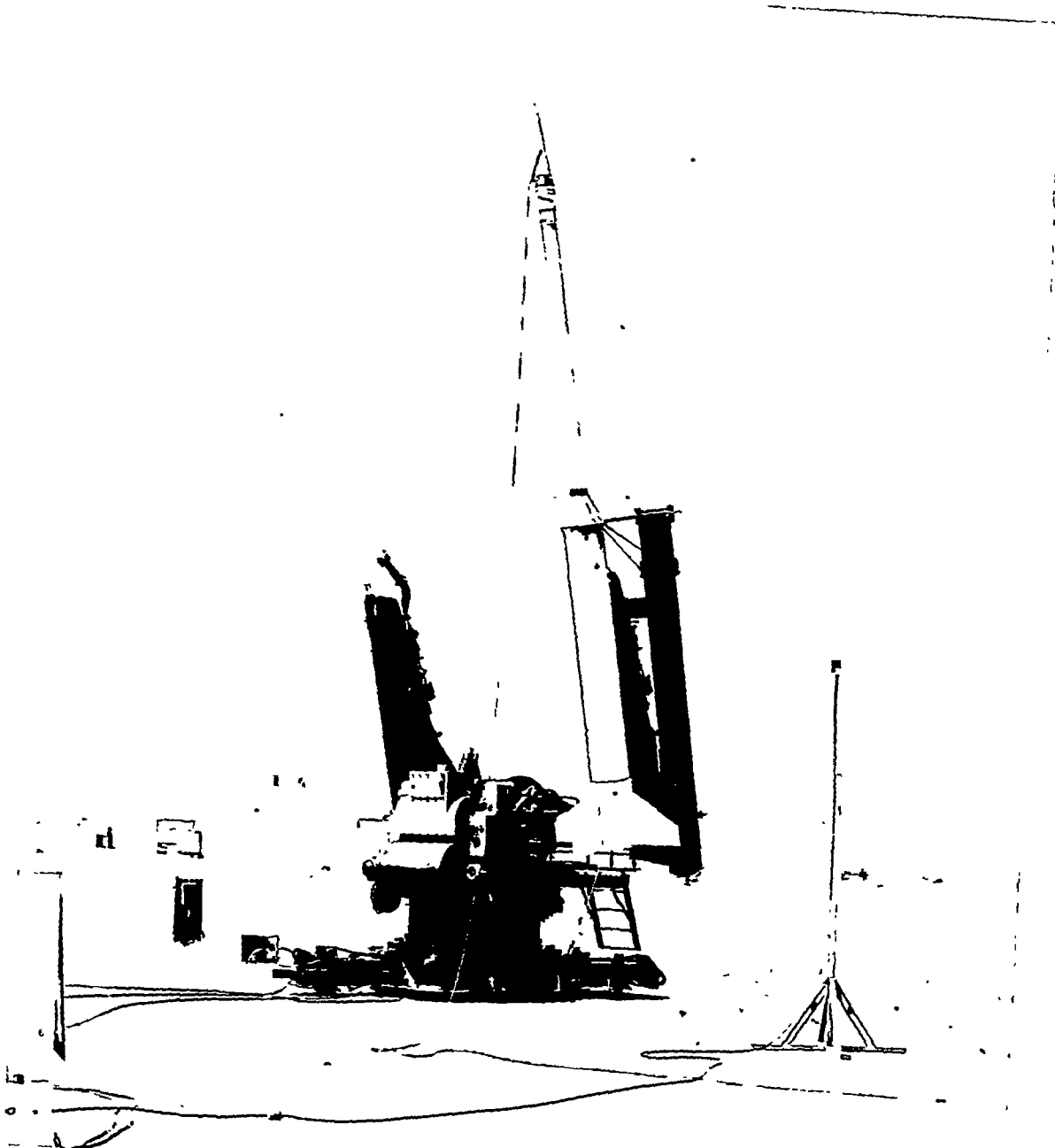


Figure 1.- Photograph showing the ABL Deacon sounding rocket and the Nike booster on launcher. L-90092.1

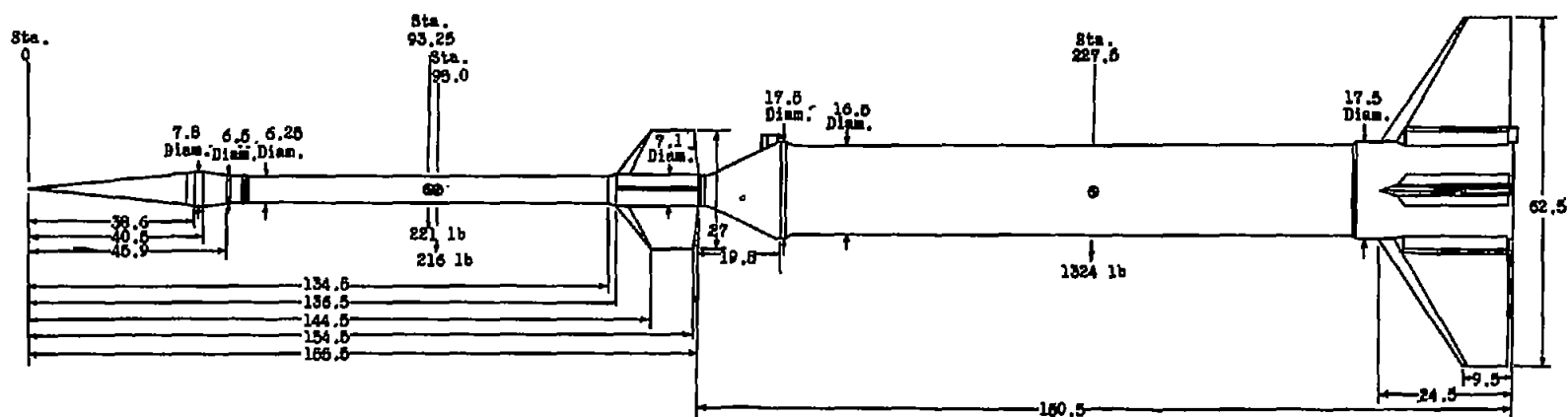
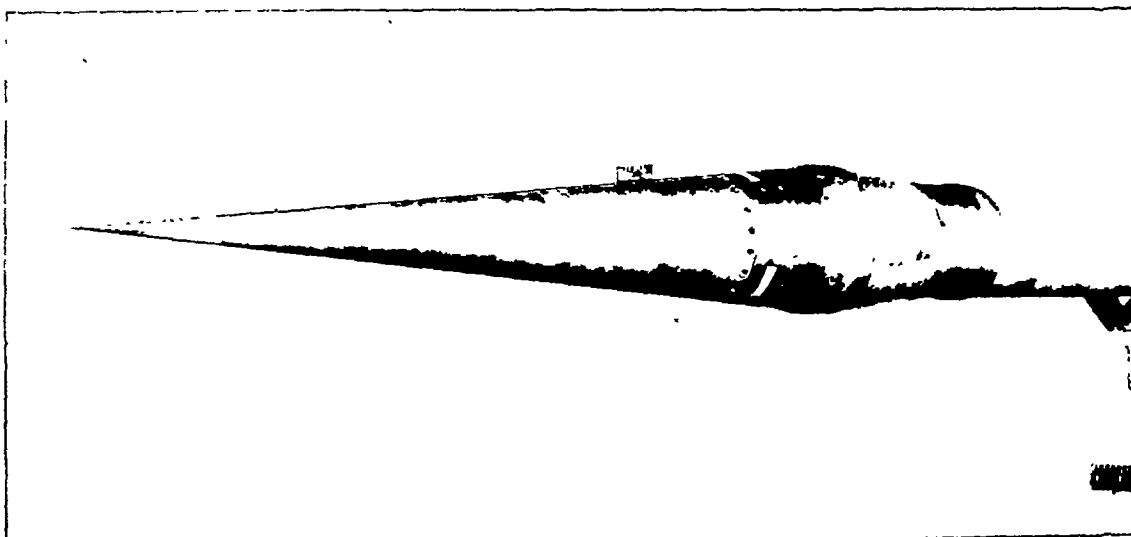
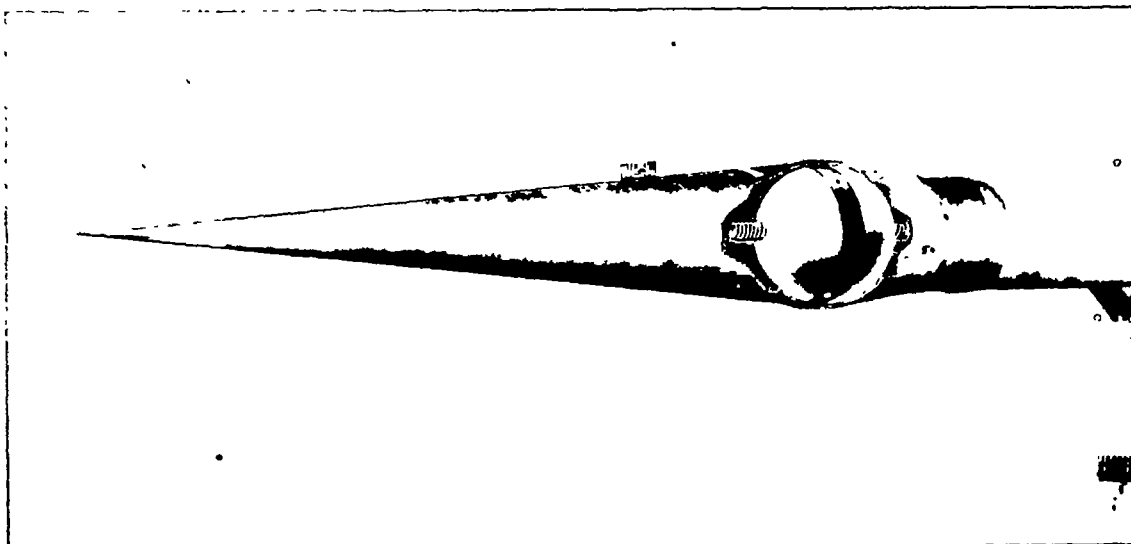


Figure 2.- General arrangement of the Nike-Deacon rocket showing pertinent dimensions and center-of-gravity locations. All dimensions are in inches unless otherwise specified.

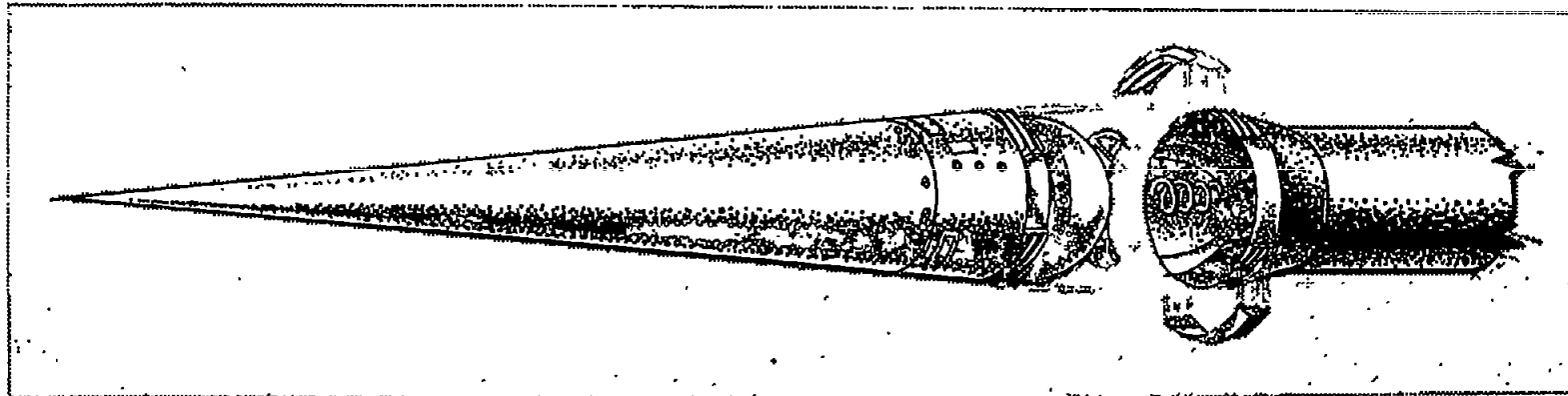


(a) Photograph of nose cone.

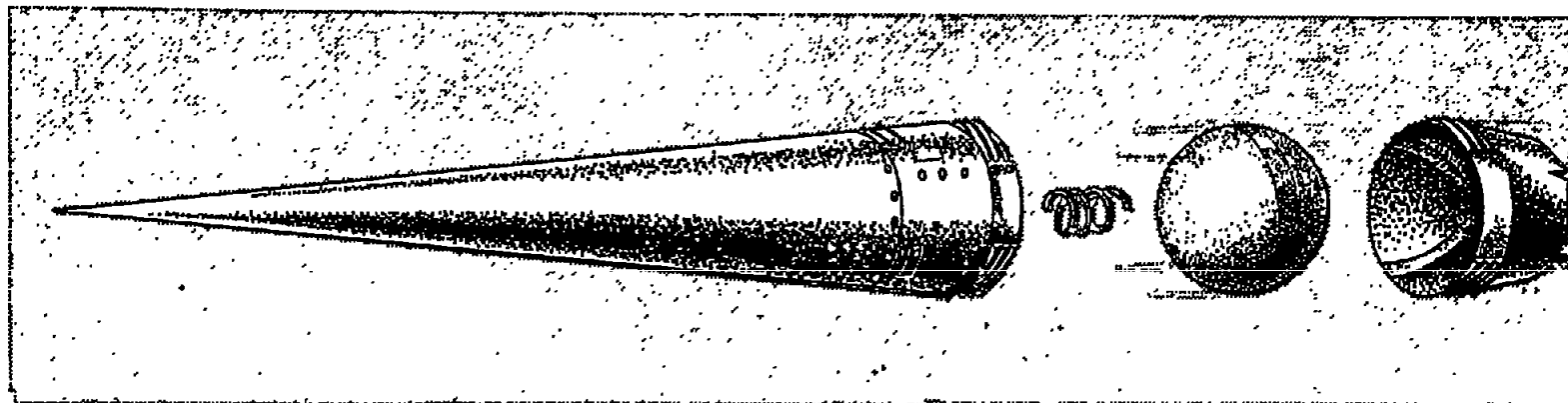


(b) Cutaway showing accelerometer sphere. L-91690

Figure 3.- Second-stage nose cone.



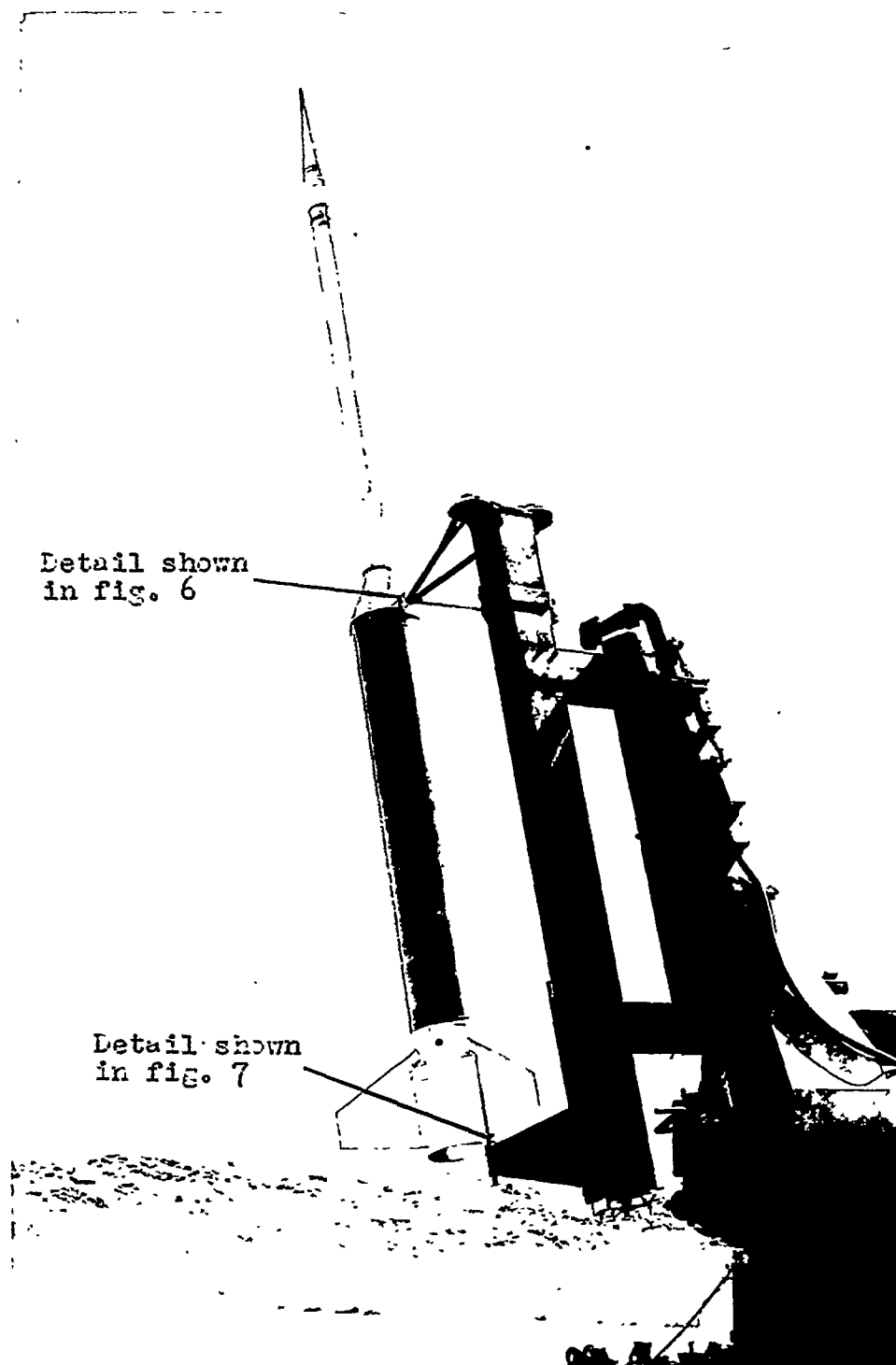
(a) Release of the nose cone and the sphere from the second-stage rocket.



L-91691

(b) Ejection of the accelerometer sphere from the nose cone.

Figure 4.- Schematic sketch of sequence release of the nose cone from the second-stage rocket.

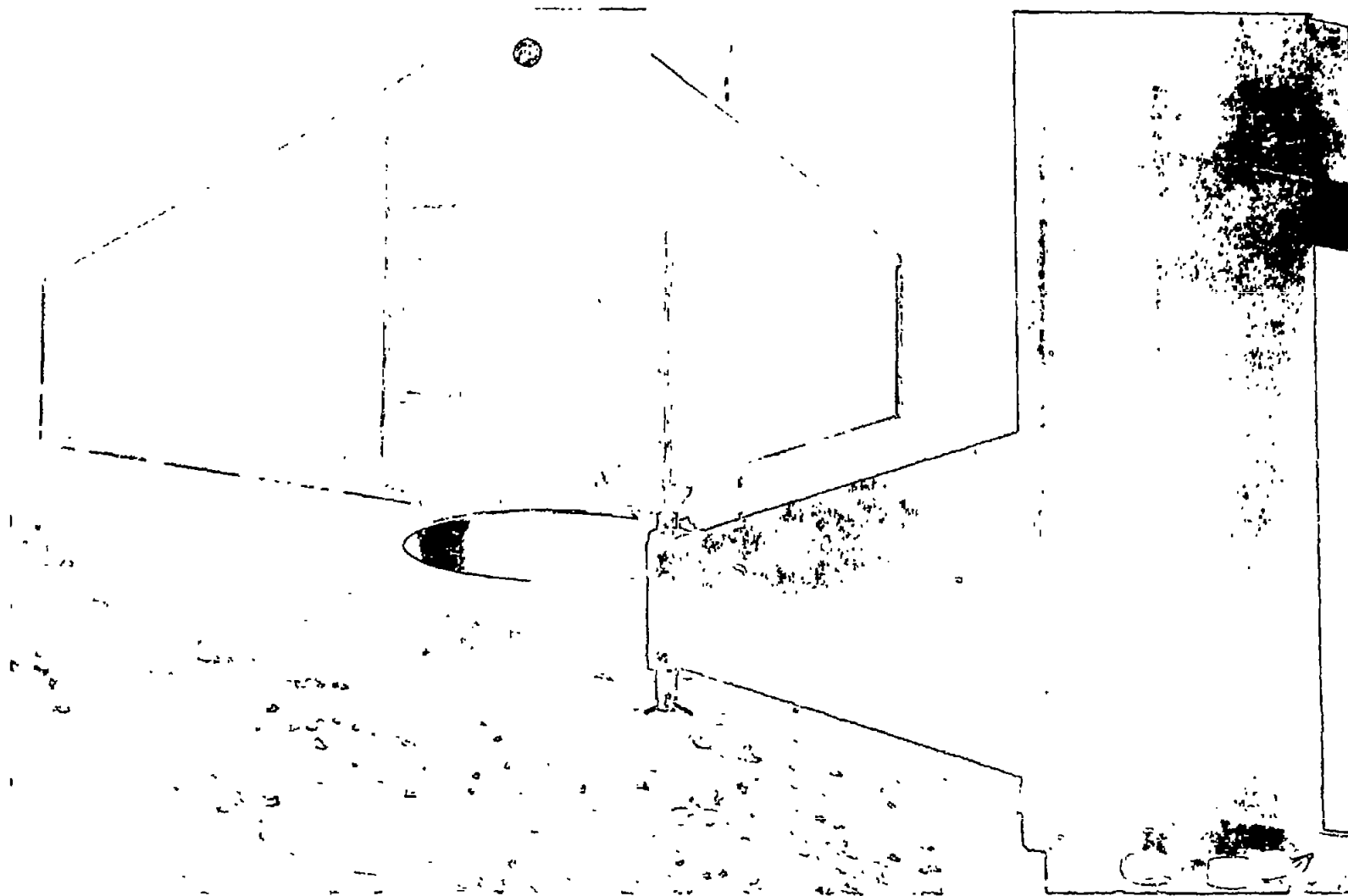


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Figure 5.- Photograph of the vehicle on the launcher showing the launching fittings.



L-91692

Figure 6.- Detailed photograph of the forward launcher fitting.



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Figure 7.- Detailed photograph of the rear launcher fitting.

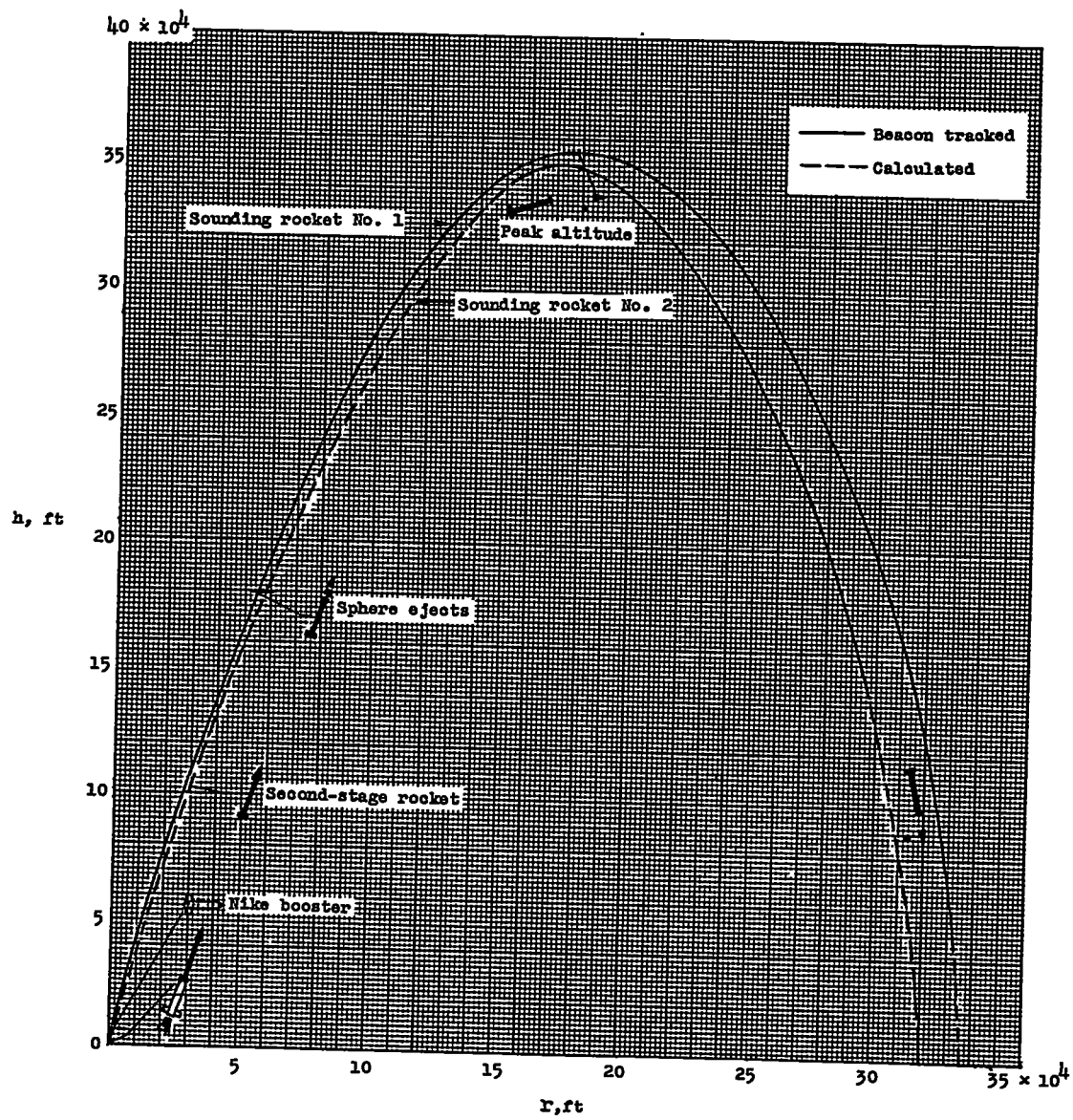


Figure 8.- Trajectories of the sounding rockets.

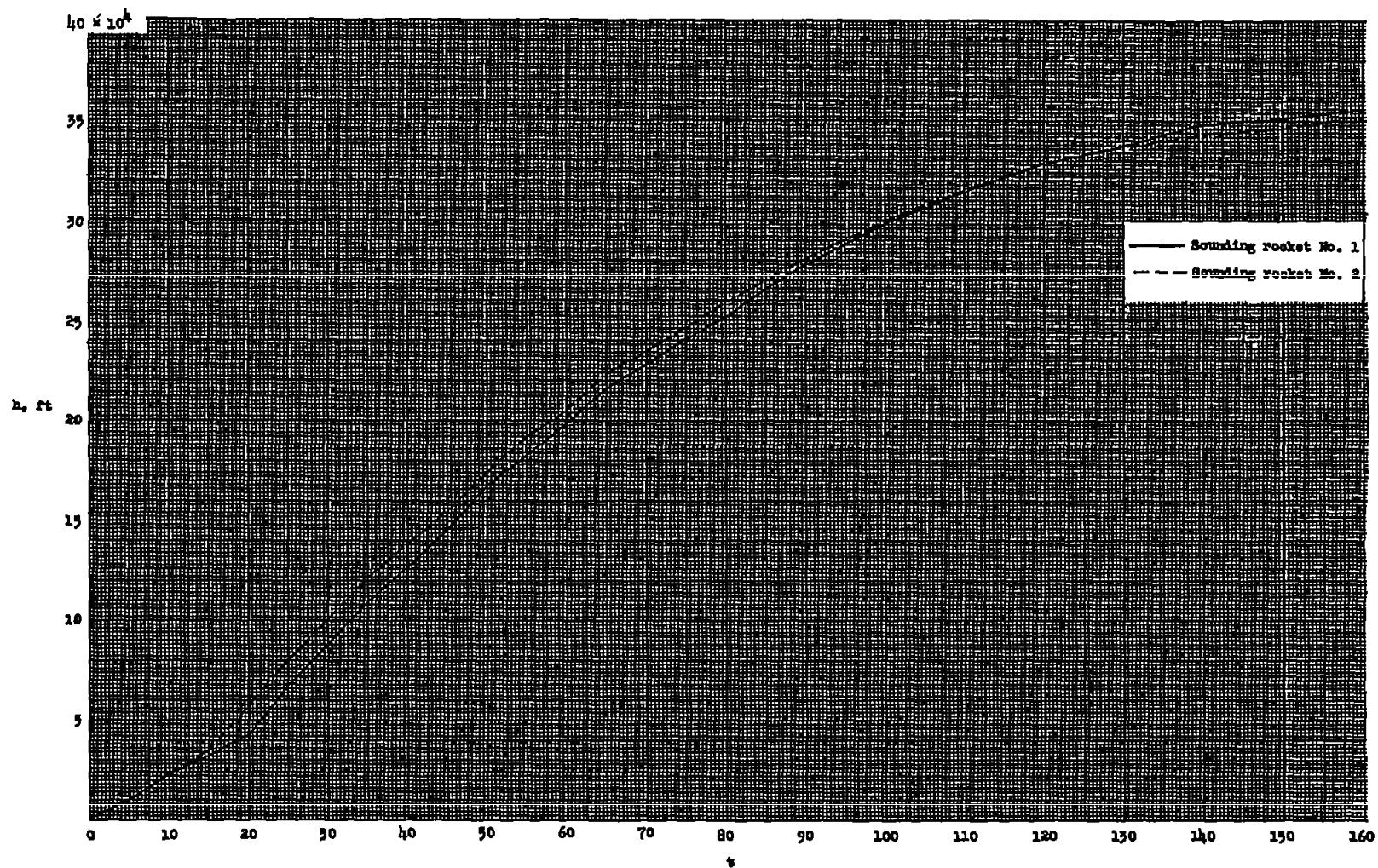


Figure 9.- Variation of altitude with time.

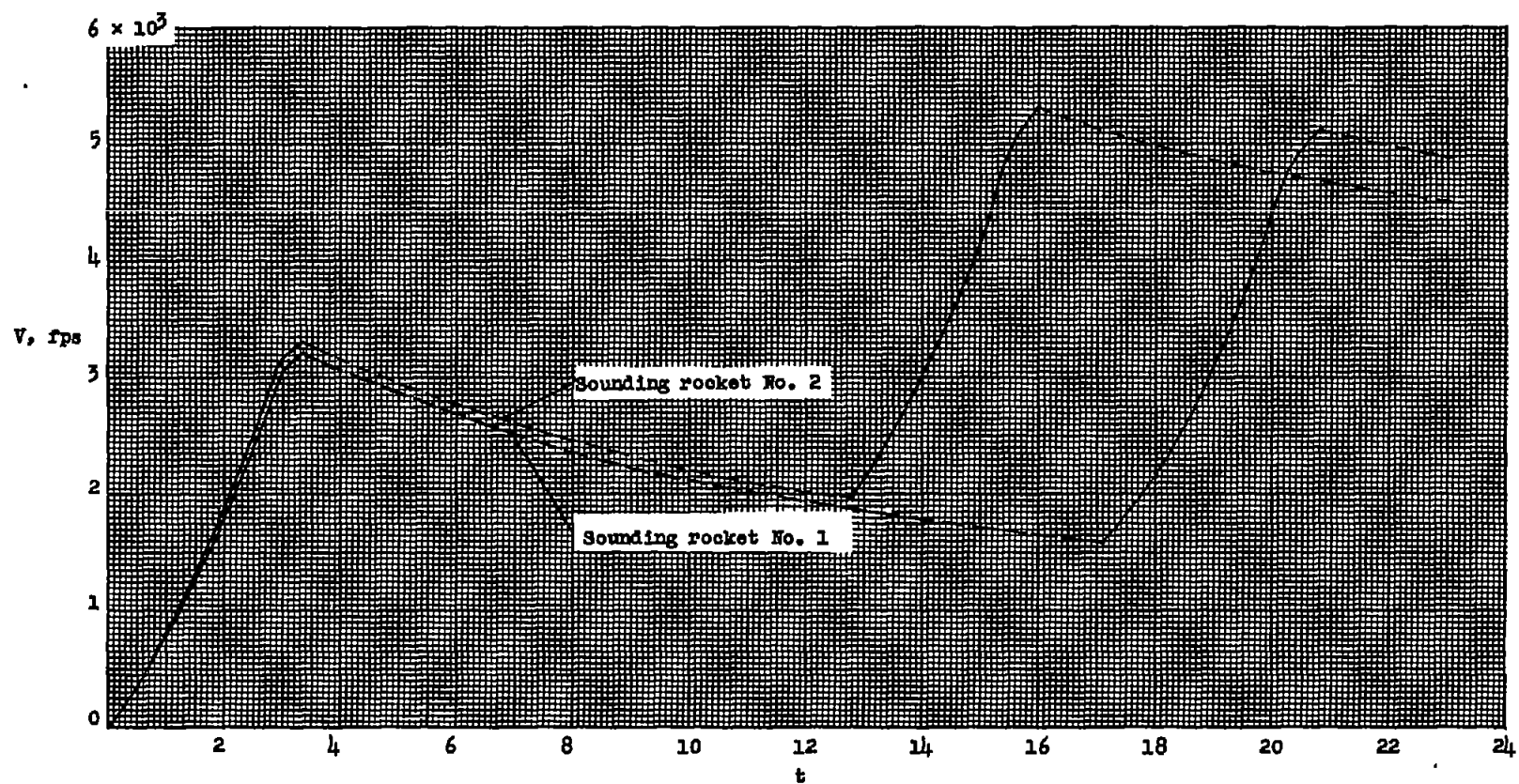


Figure 10.- Variation of velocities with time.

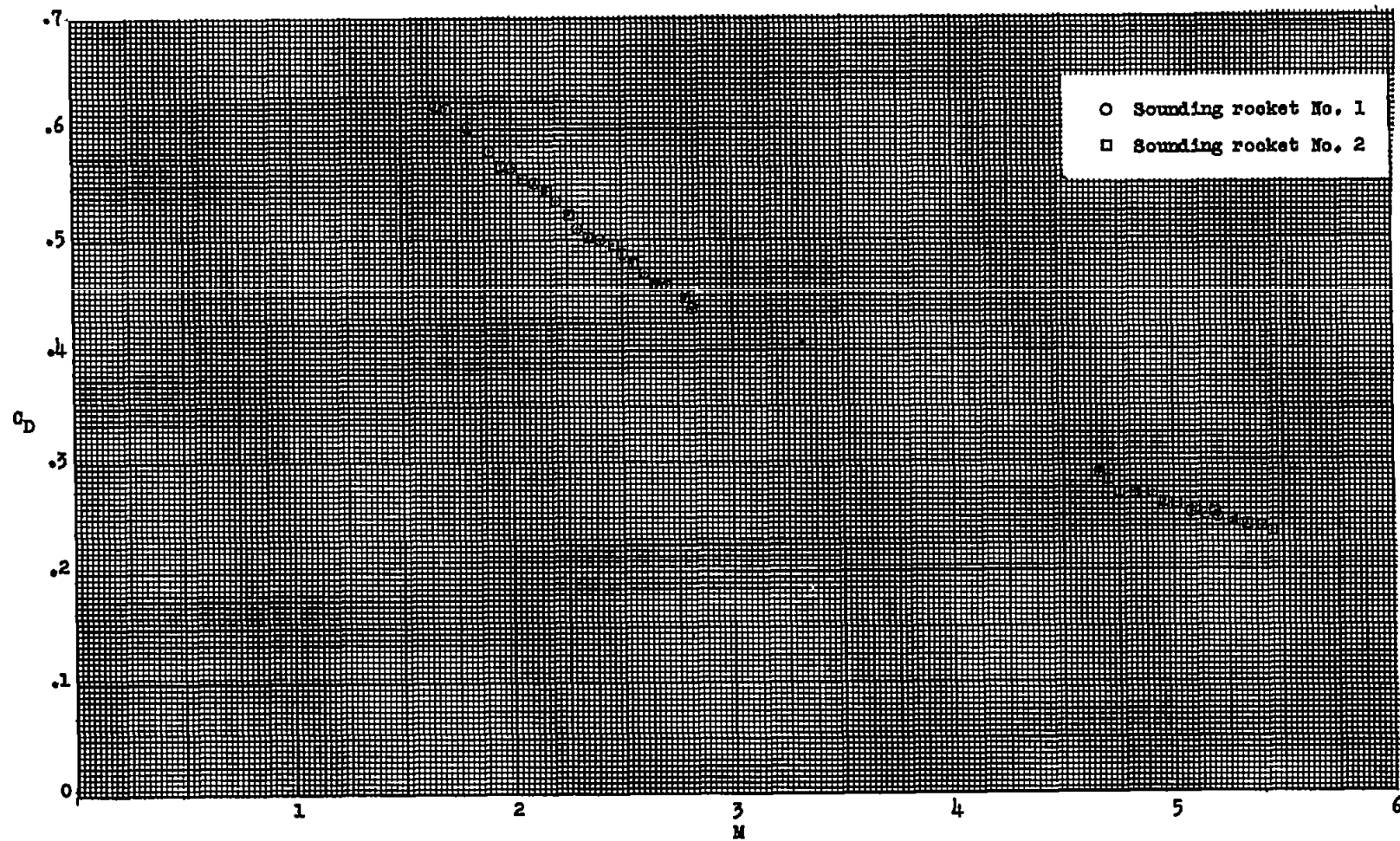


Figure 11.- Variation of drag coefficients with Mach number.

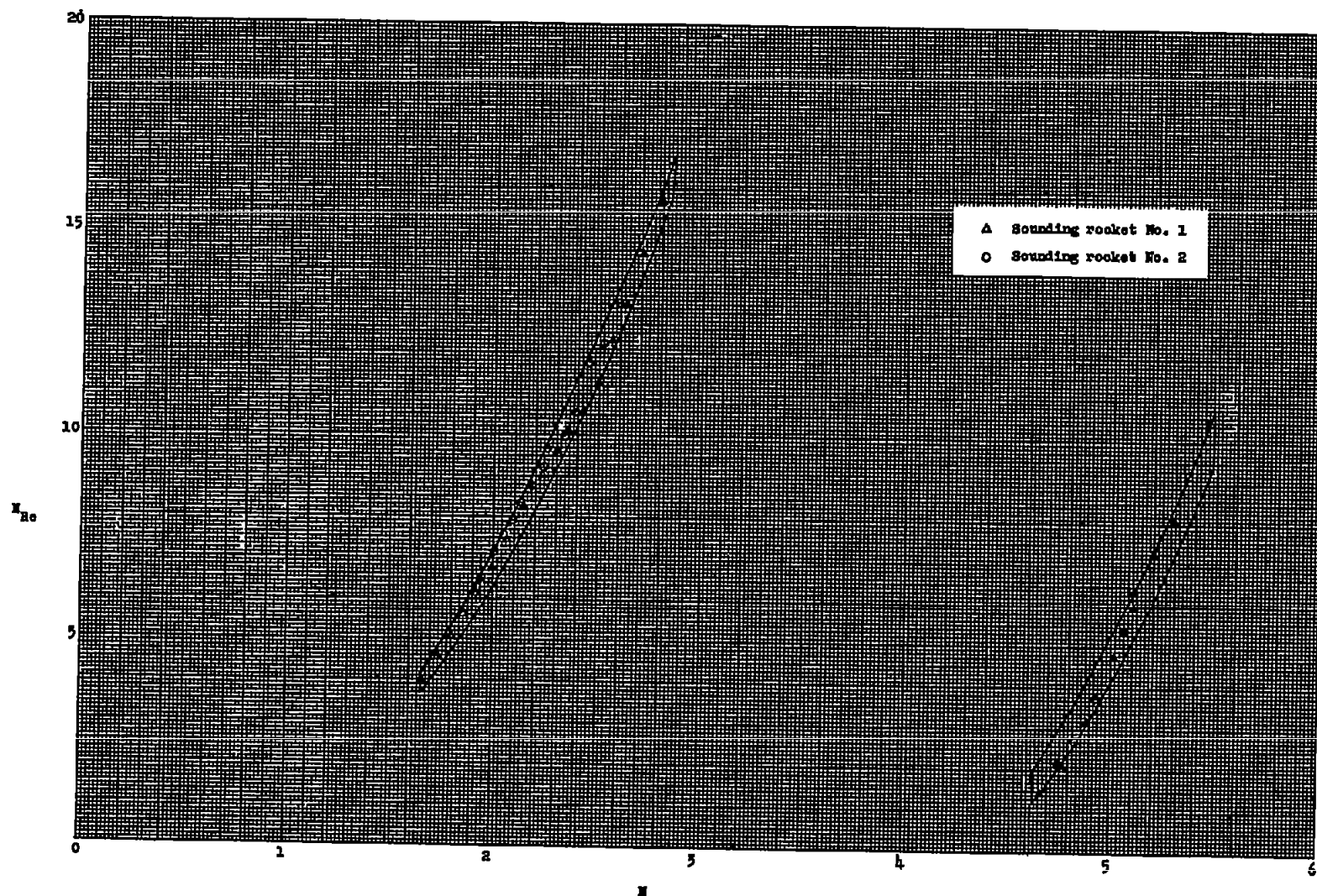


Figure 12.- Variation of Reynolds number per foot of length with Mach number.

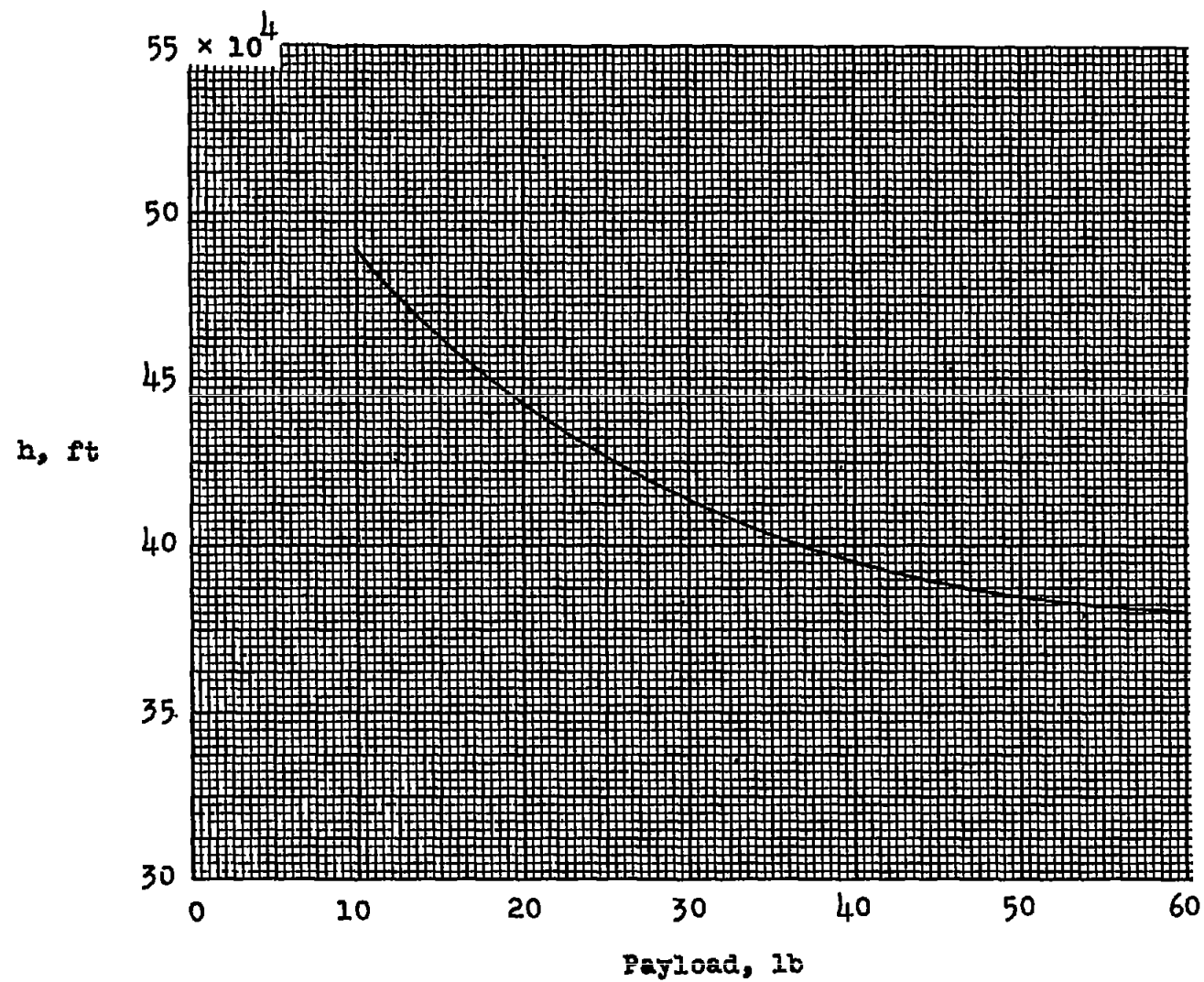


Figure 13.- Calculated variation of peak altitude with payload for vertical launching.

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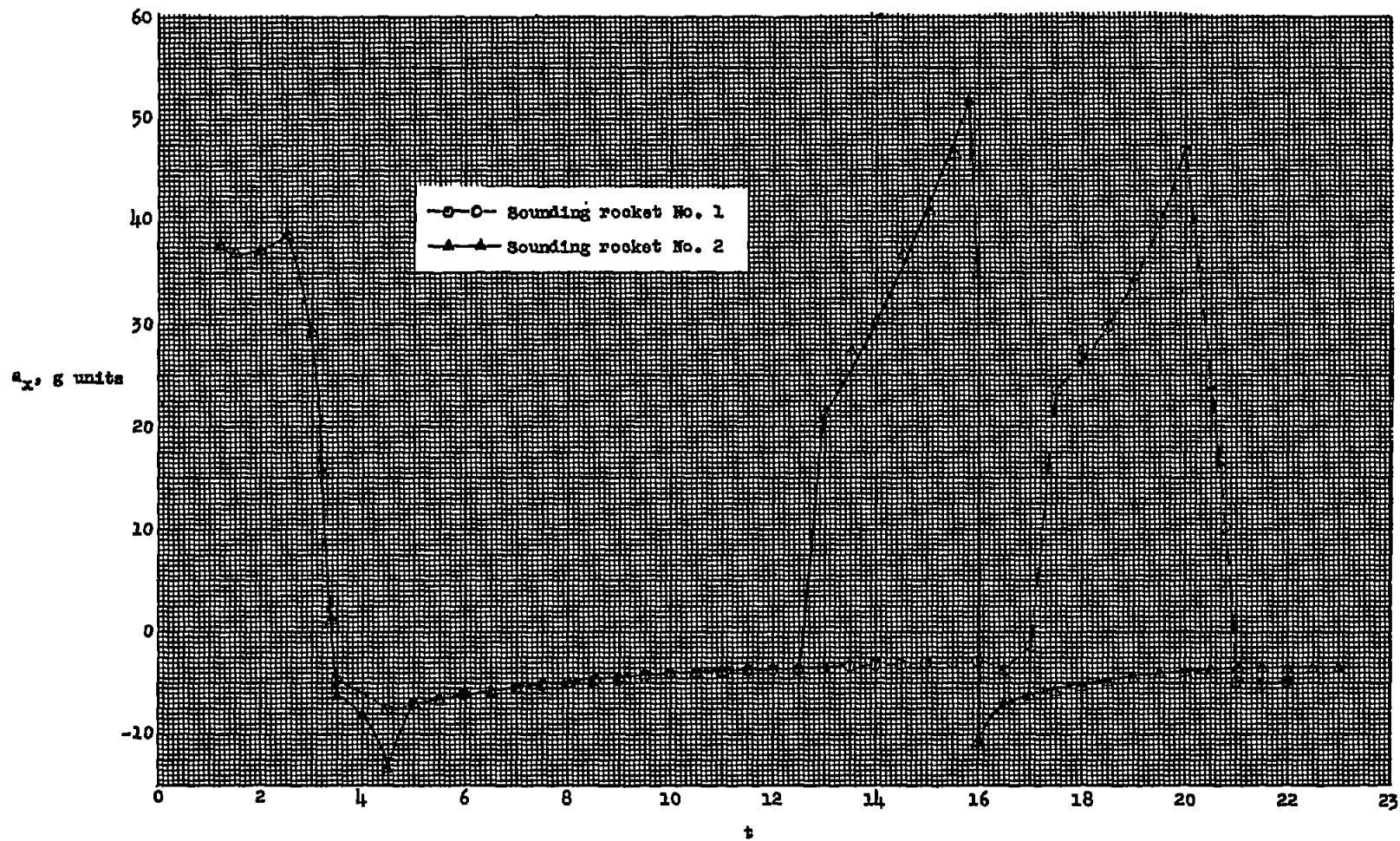


Figure 14.- Longitudinal acceleration of the sounding rockets with time.